PIB 1842

PHYTOTOXICOLOGY ASSESSMENT SURVEY INVESTIGATION IN THE VICINITY OF AMERICAN-STANDARD, CAMBRIDGE - 1989

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Introduction

As a result of a vegetation complaint investigation conducted in 1988, Phytotoxicology investigators suspected that the American-Standard (A-S) plant was a source of boron and fluoride emissions. Severe foliar injury to a large number of plant species was observed and documented. Analysis of sampled foliage showed that boron, and in some cases fluoride concentrations, were extremely elevated. Although the soil at the complaint site was relatively fresh, analysis showed that the available boron level at the 0-5 cm depth exceeded the 1 ppm (hot water soluble) concentration considered to be phytotoxic to plants.

Following the complaint investigation, Phytotoxicology investigators conducted a visual survey of vegetation in the vicinity of the American-Standard plant. The survey disclosed the presence of boron and/or fluoride injury symptomatology on vegetation at a number of locations close to the factory, although symptoms disappeared with increased distance from the plant.

Based on the information gathered from the complaint investigation and the visual survey, it was apparent that the American-Standard plant was a source of phytotoxic emissions and that a detailed vegetation and soil surveillance survey was warranted.

Phytotoxicology Survey

On August 31 and September 6, 1989 Phytotoxicology investigators conducted a survey at 18 sites in the vicinity of the American-Standard plant to assess the character, magnitude and extent of pollution effects on vegetation and soils (Figure 1). With the approximate centre of the A-S plant as the apex, the survey sites were established along six radii in order to provide comprehensive coverage of the surveillance area. Because prevailing summer winds are from the south and southwest directions, the downwind (NE) and upwind (SW) radii were extended farther and contained more survey sites. In most cases, distances of sites along each radius were relatively equidistant from the American-Standard plant.

At each site, vegetation was examined for air pollution injury symptoms and observations were recorded. Injury severity ratings and percentage of injured leaves on plants were the main parameters assessed.

Following the observational phase of the survey, Norway maple or silver maple foliage was collected in duplicate for chemical analysis. Amur maple was selected at site 1 because neither of the preferred species was available. At all sites, sample foliage was collected from tree crown aspects facing the American-Standard plant. At site 12, no suitable sample species was available. Photographs were taken at sites

where severe foliar injury was observed and leaf samples were collected for the herbarium.

At each of the 18 survey sites, duplicate soil samples were collected for analysis from undisturbed locations at 0-5 cm and 25-30 cm depths. Normally, a standard soil core borer is used to obtain soil samples from relatively shallow depths. At greater depths and under dry soil conditions, the borer is ineffective. Because conditions in survey area soils were dry, a narrow spade was used to create mini pits approximately 11 cm square and 30 cm deep. At each site, a total of four mini soil pits were excavated. One set (0-5 cm and 25-30cm) of the duplicate samples were obtained from two pits, the second set from the other two pits.

Foliar and soil samples were submitted to the Phytotoxicology laboratory for processing. Foliage and soils were processed according to standard methods developed for each. The unwashed and oven-dried foliar samples were submitted to the Ministry's Inorganic Trace Contaminants laboratory (ITC) for total boron and fluoride analysis as well as for 6 other elements. The air dried and sieved soil samples were also submitted to the ITC lab for analysis of eight elements, as well as tests for available boron by the hot water extract method.

Visual Observations

At each of the 18 survey sites, vegetation was examined for air pollution injury symptoms. Table 1 is a summary of these observations. Injury to vegetation was most severe at those sites (1, 5, 8, 10 and 12) closest to the American-Standard plant. Most injury affected the terminal, marginal and intercostal portions of the foliage and was characteristic of symptomatology induced by boron and/or fluoride. Injury severity and the percentage of foliage affected declined noticeably with increased distance from A-S along each radius.

Chemical Analysis Results - Foliage

Concentrations of 8 elements detected in vegetation sampled at 17 of the survey sites are presented in Table 2. Values which exceeded the Phytotoxicology Upper Limit of Normal guideline (ULN) are underlined. The rationale for the ULN appears in Appendix I.

Contour maps were created to demonstrate the relationships between values of eight elements found in maple foliage at the survey sites and the A-S plant. The maps were computer-generated (Surfer) and the isometric lines link values of similar concentrations. Although contour locations at the sample sites are accurate, some computer extrapolation may exist between sites. Therefore, the predicted concentration at any point other than the sample point is a computer-generated 'best guess'.

Boron concentrations which exceeded the Phytotoxicology ULN of 175 ppm were found in vegetation at 12 of the 17 survey sites (Table 2). The contour map shows that foliar boron values were highest at all sites closest to the source, but decreased with increasing distance from the A-S plant (Figure 2).

Fluoride values in excess of the ULN guideline of 35 ppm were detected in foliage at 2 survey sites - both close to the A-S plant. The highest value (68 ppm) was found at site 1 and 67 ppm at site 8 (Table 2). Fluoride values found in the vegetation declined with increased distance from the source (Figure 3).

Although concentrations of nickel detected in foliage were elevated at sites closest to the A-S plant, only the value at site 16 (8.6 ppm) exceeded the 7 ppm ULN guideline. Nickel values dropped sharply at sites farther from the source (Figure 4).

The concentrations of the other elements in the sampled foliage - titanium, barium, copper, zinc, and lead were below their respective ULN's. However, compared to control values, levels of these elements were elevated at sites closest to A-S but declined with increased distance (Figures 5-9).

Chemical Analysis Results - Soil

Available Boron

The concentration of available boron found in 0-5 cm and 25-30 cm depth soils sampled at 18 survey sites in the vicinity of the American-Standard plant are shown in Table 3. Values of available boron, at or in excess of 1 ppm, are considered potentially phytotoxic.

The table shows that excessive boron values were found in 0-5 cm soils at 5 sites. Four of the sites are located closest the A-S plant. The two highest values were found at site 1 (3.7 ppm) and site 16 (2.4 ppm). There was a concomitant drop in boron values in the surface soil with increased distance from the source.

Phytotoxic values of available boron were found in the deeper 25-30 cm soil at 2 sites near the A-S plant. Values of 1.8 ppm and 1.0 ppm were found at close-in sites 1 and 8, respectively. As with the surface soil samples, boron values in the deeper soils declined with increased distance from the source.

The pattern of higher available boron values in 0-5 cm and 25-30 cm depth soils closest to the A-S plant is demonstrated in the computer-generated contour maps (Figures 10-11).

Total Elements

Total values of 8 elements (boron, fluoride, barium, titanium, zinc, copper, nickel and lead) detected in 0-5 cm soils collected in the vicinity of A-S have been compiled in Table 4. Values which exceeded their ULN guideline have been underlined.

Total boron exceeded the Phyto ULN guideline of 15 ppm at 8 of the 18 survey sites. With the exception of site 7, sites with excessive boron values are located closest to the A-S plant (Figure 12).

Fluoride (Figure 13), barium (Figure 14) amd titanium (Figure 15) values found in 0-5 cm soils were all below their respective ULN guideline although all values tended to be more elevated than the controls particularly at sites closest to the A-S plant.

Excessive zinc values in 0-5 cm soil were found at sites 13 and 17. Generally, values of the metal were higher near the A-S plant but dropped off with increased distance (Figure 16).

Copper (Figure 17) and lead (Figure 18) values exceeded their respective ULN guidelines at site 17. At the remaining locations, values of both elements were higher at sites closest to A-S.

Nickel values in excess of the ULN guideline of 60 ppm were detected at sites 1 (70 ppm) and 17 (115 ppm)(Figure 19). Values of the metal at sites near A-S were, again, generally more elevated than at sites farther from the plant.

The vegetation and soil maps reveal an apparent duality of concentration centres. The analysis data show that, with the exception of boron and fluoride, the highest soil concentrations were consistently detected at site 17. Conversely, the maps show that the higher elemental values found in the vegetation were centred around sites 1 and 16. Since soil values tend more to reflect historical rather than current emissions, it is likely that the elevated values detected in the soils at site 17 may be, in part, residual materials from some unknown previous industrial activity.

Conclusions

Severe visual injury was observed on a variety of vegetation species at sites close to the American-Standard plant in Cambridge. The severity and incidence of injury declined sharply in all directions with increased distance from the plant. The injury symptomatology appeared to be characteristic of that induced by boron and/or fluoride.

Chemical analysis results of sampled foliage indicated that values of boron were in excess of the Phytotoxicology Upper Limit of Normal

guideline at 11 of the 17 survey sites. Values of the element at sites close to A-S were considered to be extremely high.

Excessive fluoride values were found in foliage at 2 sites closest to the American-Standard plant. Nickel in excess of the ULN guideline was found at one site close to the plant. Values of the other elements were more elevated (compared to the controls) at sites near the plant but dropped off with increased distance.

Values of available boron in excess of the concentration considered to be phytotoxic (above 1 ppm) were found in 0-5 cm soil at 5 sites and at 2 sites for 25-30 cm soil. These levels in soil would have contributed to the elevated foliar concentrations detected at these sites.

Excessive total boron concentrations in 0-5 cm soil were detected at 8 of 18 survey sites. Values of zinc and nickel exceeded the ULN guidelines at 2 sites, while copper and lead concentrations were both found to be excessive at one site.

Based on the visual and analytical data, it appears certain that boron emissions from the American-Standard plant have injured vegetation and contaminated soils in a relatively large surrounding area. The data also indicated the presence of elevated or excessive values of fluoride, barium, titanium, zinc, nickel and lead in foliage and fluoride, titanium, zinc, copper, nickel and lead in soils collected near the plant.

The high values of zinc, copper, nickel and lead found in soils at site 17 are not suspected of being elements which have been emitted from the A-S plant. Since the historical background of the soil at site 17 is unknown, the high zinc, copper, nickel and lead values found in the 0-5 cm soils may be due to emissions from a nearby foundry. In 1991, the Phytotoxicology Section may conduct a soil and/or vegetation survey in the vicinity of this foundry operation.

Appendix I

Derivation and Significance of MOE "Upper Limits of Normal" Contaminant Guidelines

The MOE "upper limits of normal" contaminant guidelines essentially represent the expected maxiumum concentration of contaminants in surface soil (non-agricultural), foliage (tree and shrub), grass, moss bags and/or snow from areas of Ontario not subject to the influence of point sources of emissions. "Urban" guidelines are based upon samples collected from centers of minimum 10,000 population. "Rural" guidelines are based upon samples collected by MOE personnel using standard sampling techniques (ref: Ministry of the Environment, 1983. Field Investigation Manual. Phytotoxicology Section - Air Resources Branch: Technical Support Sections - NE and NW Regions). Chemical analyses were performed by the MOE Laboratory Services Branch.

The guidelines were calculated by taking the arithmetic mean of available analytical data and adding three standard deviations of the mean. For those distribution that are "normal", 99% of all contaminant levels in samples from "background" locations (i.e. not affected by point sources nor agricultural activities) will lie below these upper limits of normal. For those distributions that are non-normal, the calculated upper limits of normal will not actually equal the 99th percentile, but nevertheless they lie within the observed upper range of MOE results for Ontario samples.

Due to the large variability in element concentrations which may be present across Ontario, even in background data, control samples should always be collected. This is particularly important for soils, which show large regional variations in element composition due to difference in parent material. Species of vegetation which naturally accumulate high levels of an element also may be encountered.

It is stressed that these guidelines do not represent maximum desirable or allowable levels of contaminants. Rather, they serve as levels which, if exceeded, would prompt further investigation on a case by case basis to determine the significance, if any, of the above normal concentration(s). Concentrations which exceed the guidelines are not necessarily toxic to plants, animals or man. Concentrations which are below the guidelines are not known to be toxic.

FIGURE: 1 Locations of Phytotoxicology Vegetation and Soil Survey Sites in the Vicinity of American-Standard, Cambridge

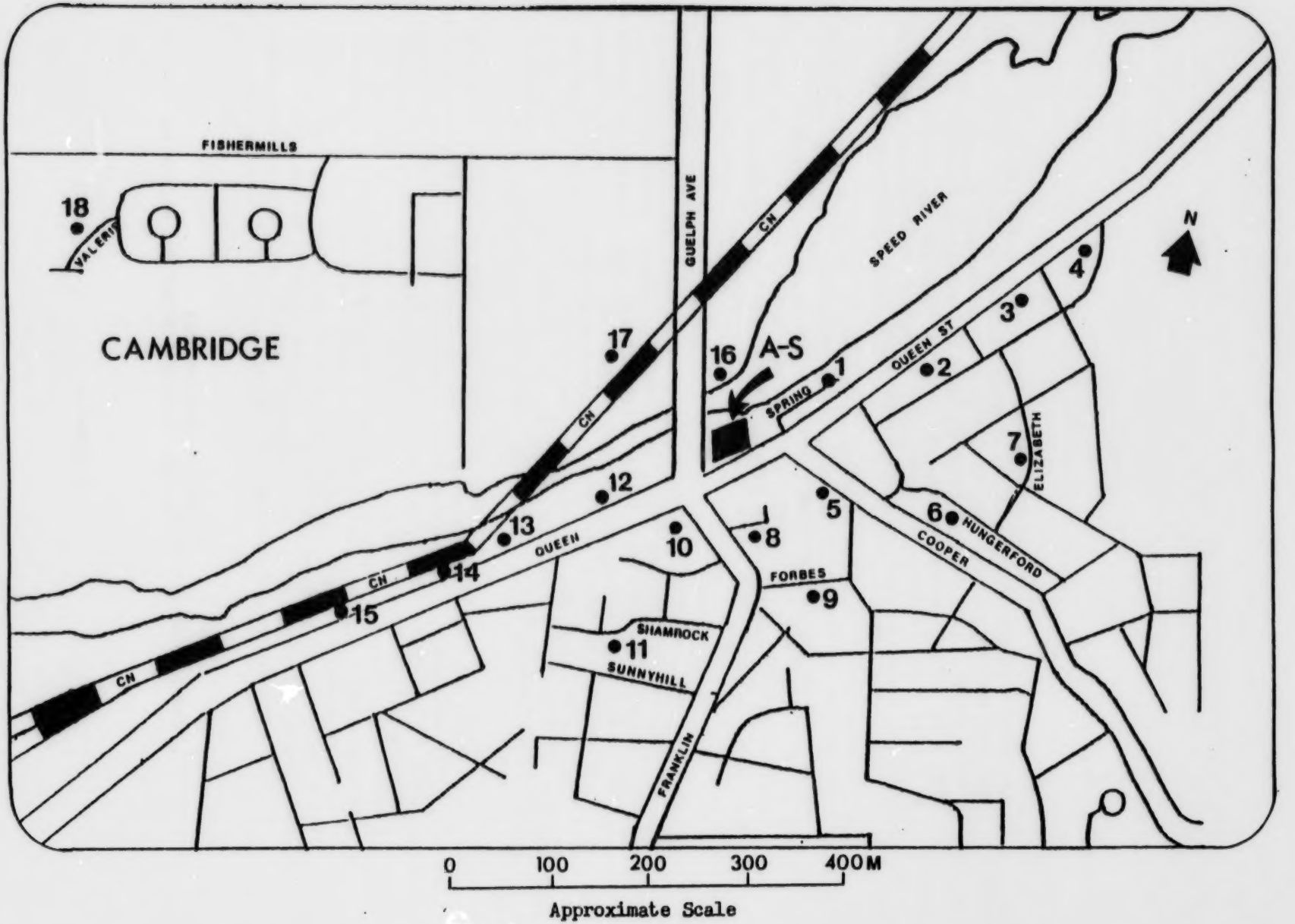
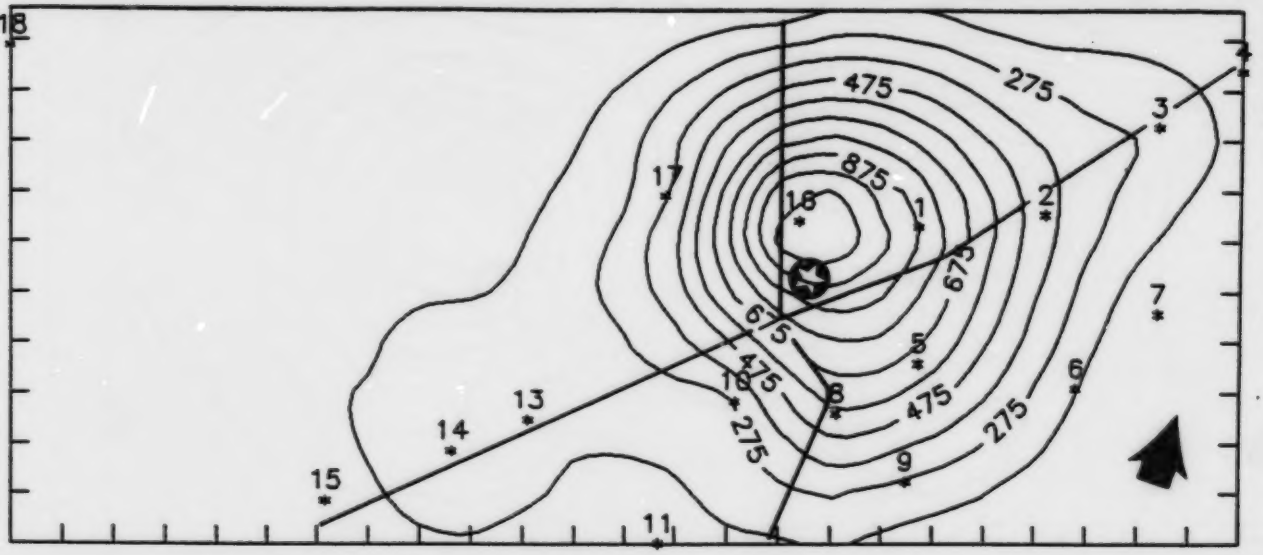
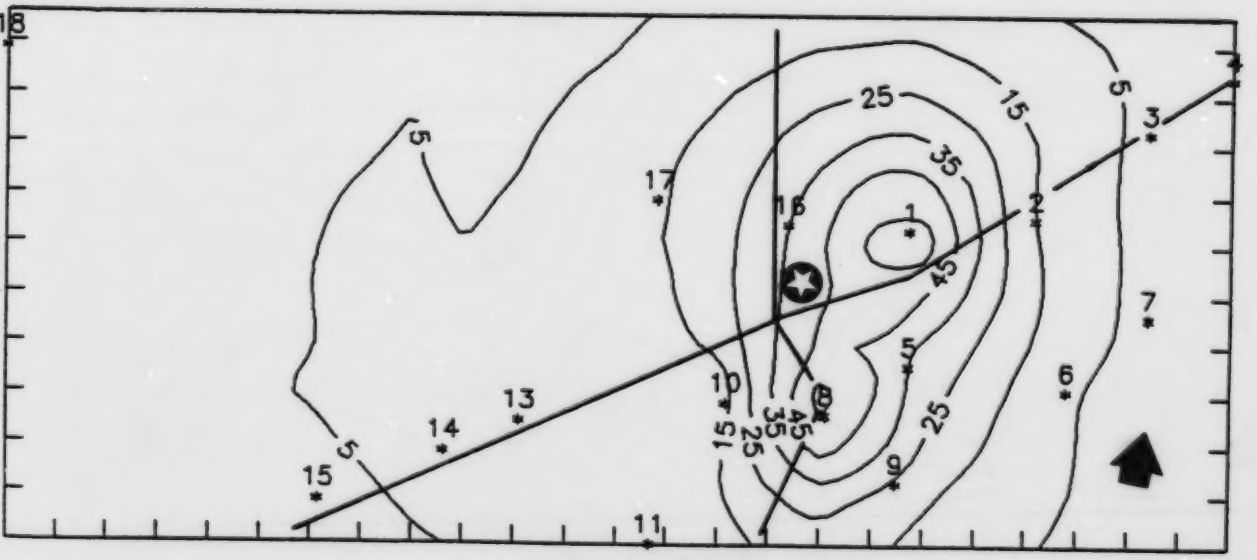


FIGURE: 2 Boron Concentrations in Maple Foliage



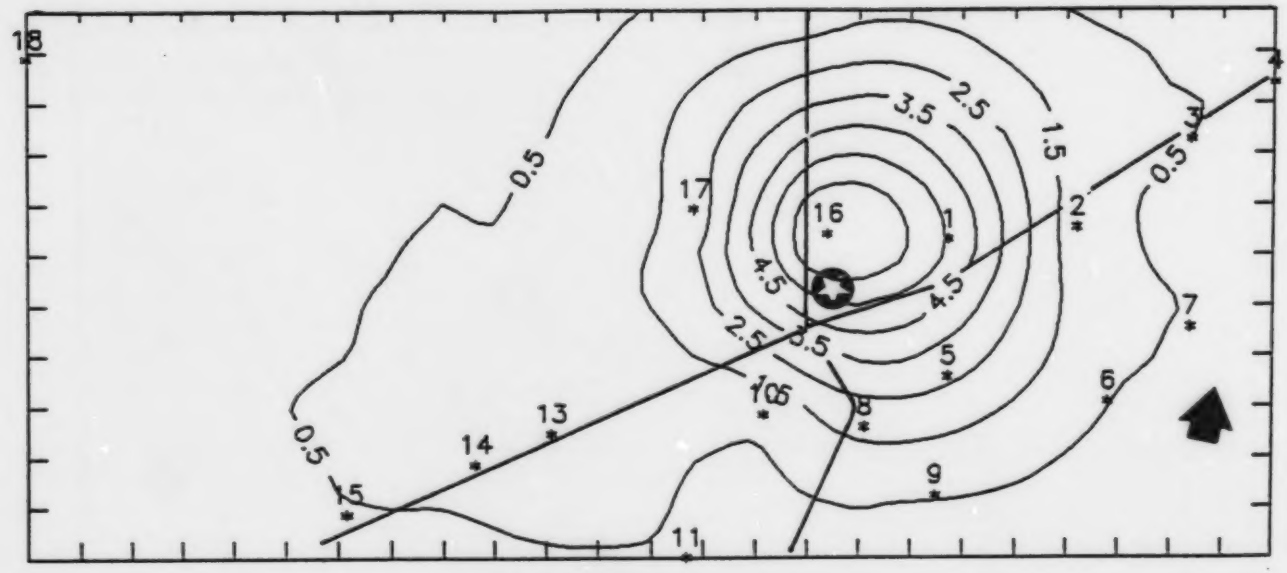
Contour Interval 100 ppm

FIGURE: 3 Fluoride Concentrations in Maple Foliage



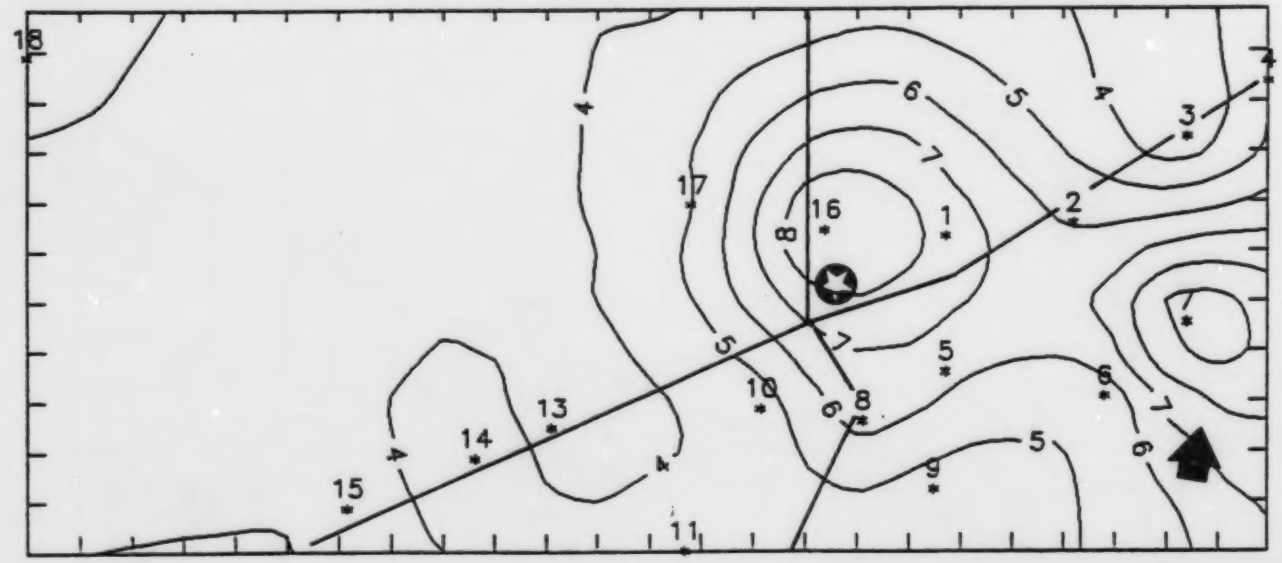
Contour Interval 10 ppm

FIGURE: 4 Nickel Concentrations in Maple Foliage



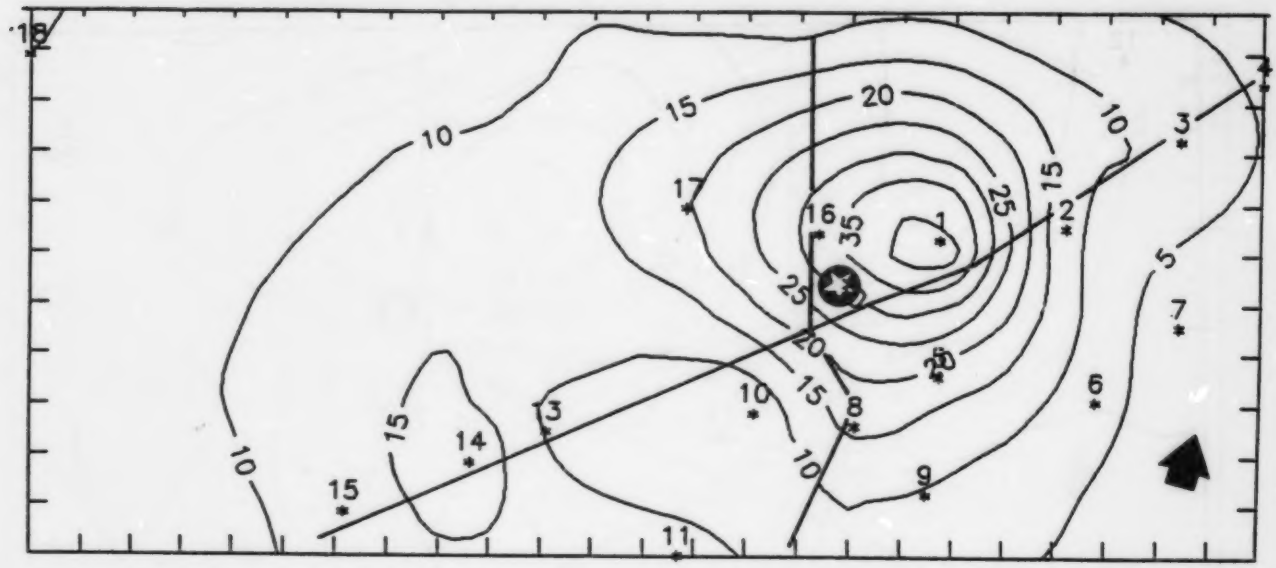
Contour Interval 1 ppm

FIGURE: 7 Copper Concentrations in Maple Foliage



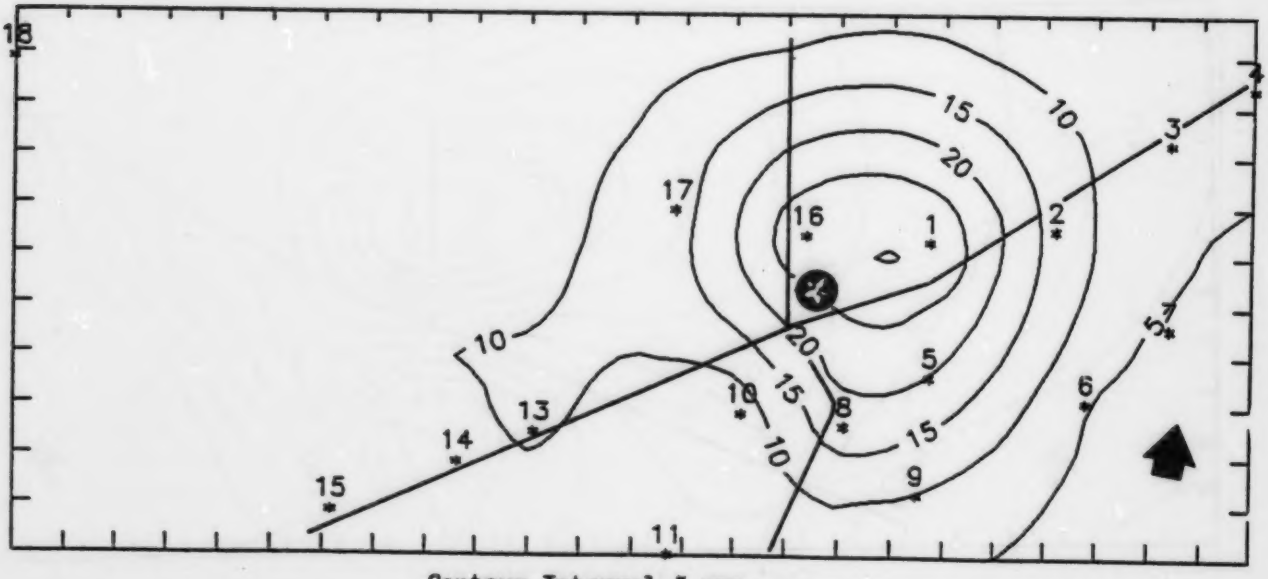
Contour Interval 1 ppm

FIGURE: 6 Barium Concentrations in Maple Foliage



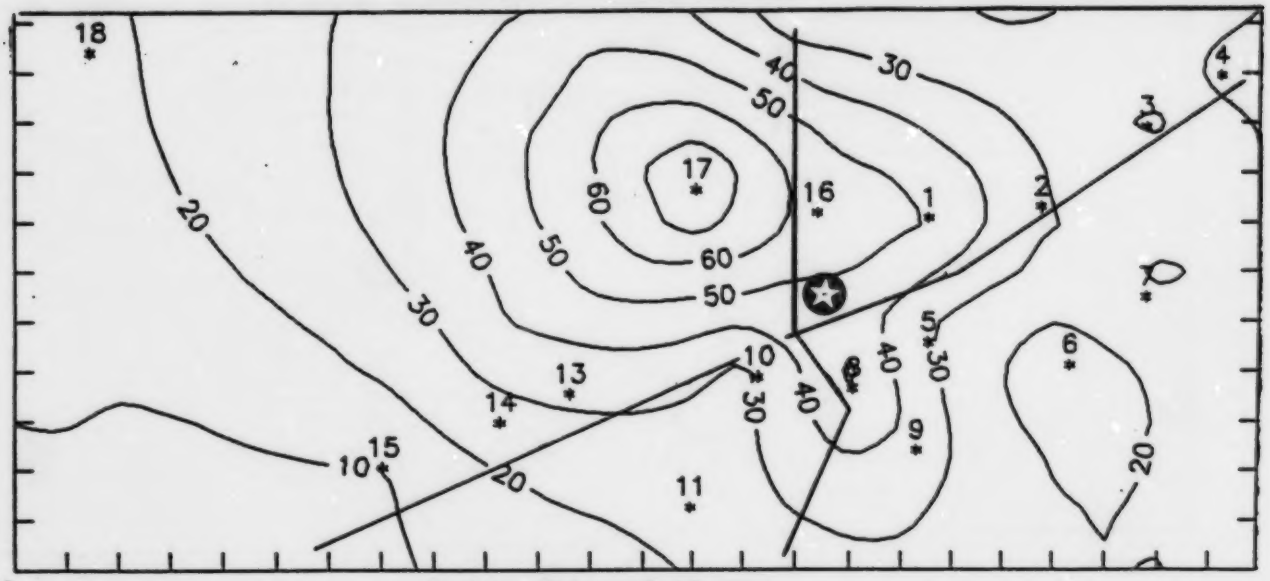
Contour Interval 5 ppm

FIGURE: 5 Titanium Concentrations in Maple Foliage



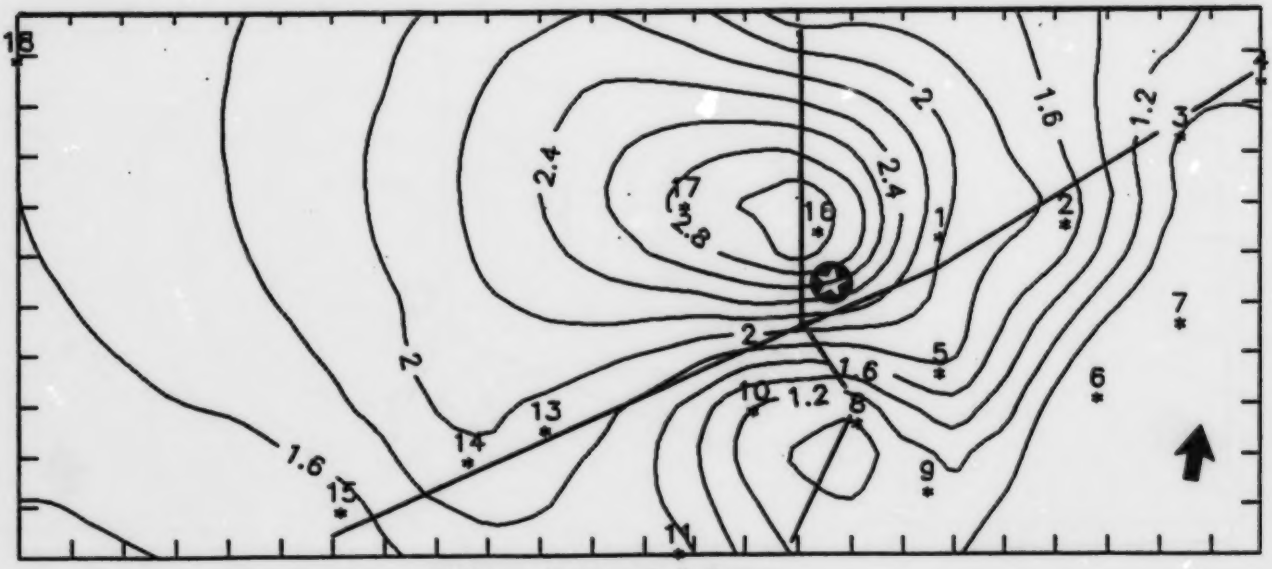
Contour Interval 5 ppm

FIGURE: 8 Zinc Concentrations in Maple Foliage



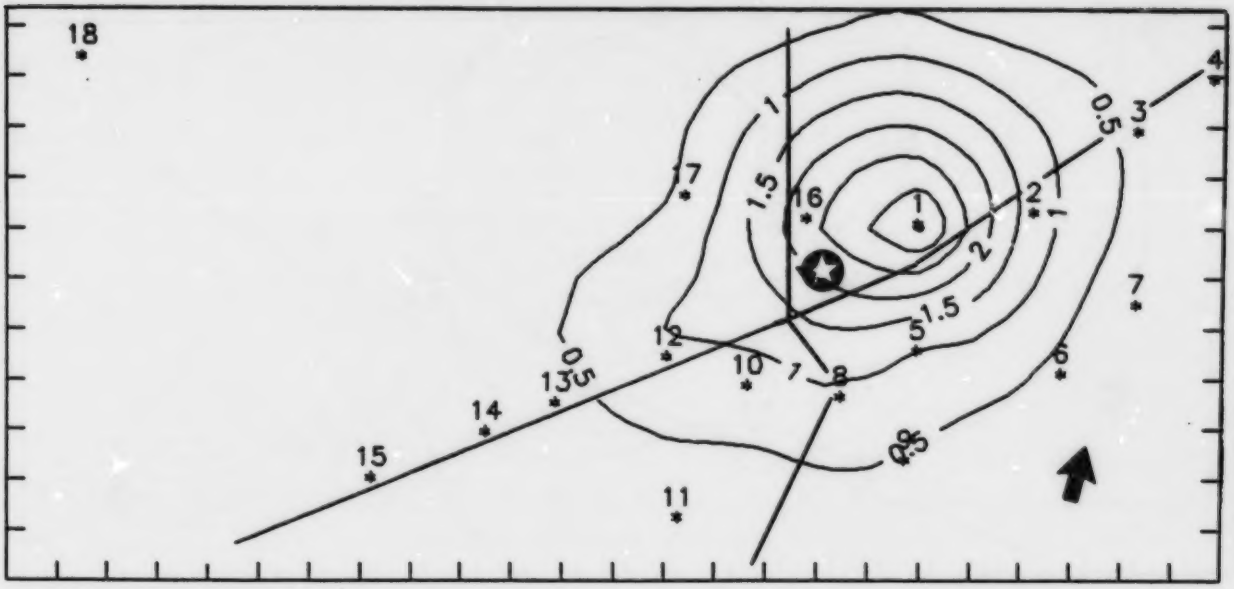
Contour Interval 10 ppm

FIGURE: 9 Lead Concentrations in Maple Foliage



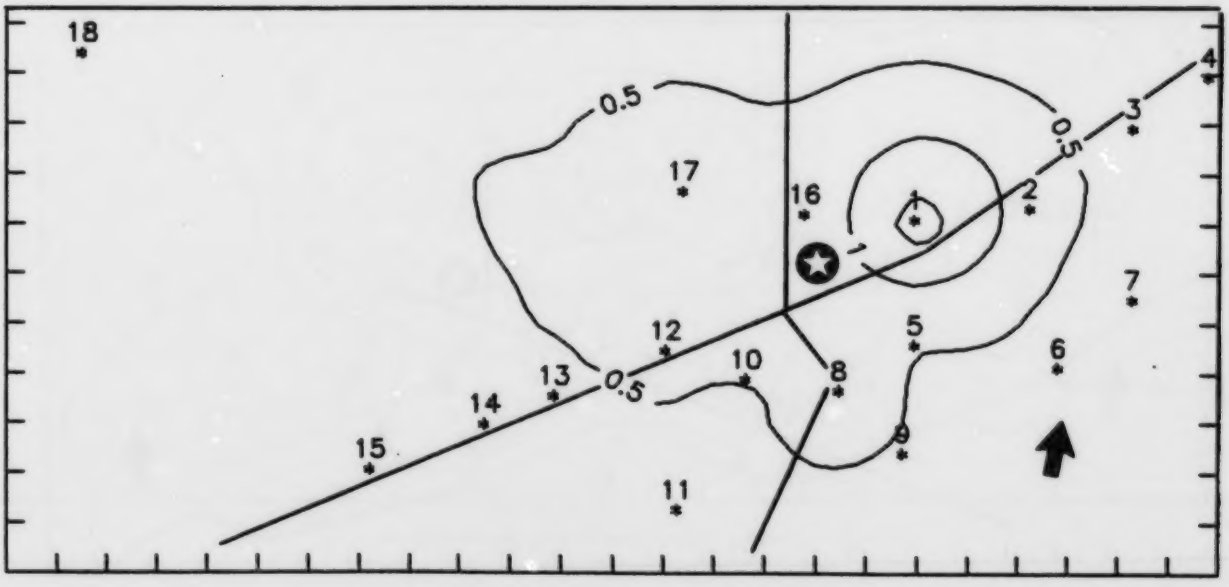
Contour Interval 0.2 ppm

FIGURE: 10 Available Boron Concentrations in 0-5 cm Soil



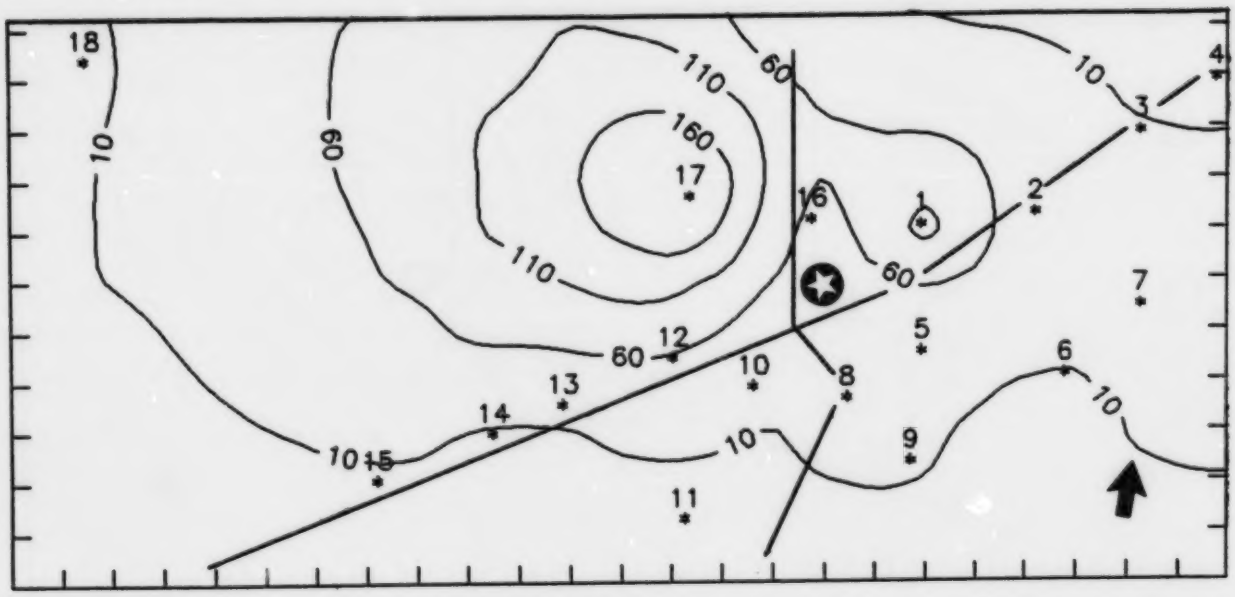
Contour Interval 0.5 ppm

FIGURE: 11 Available Boron Concentrations in 25-30 cm Soil



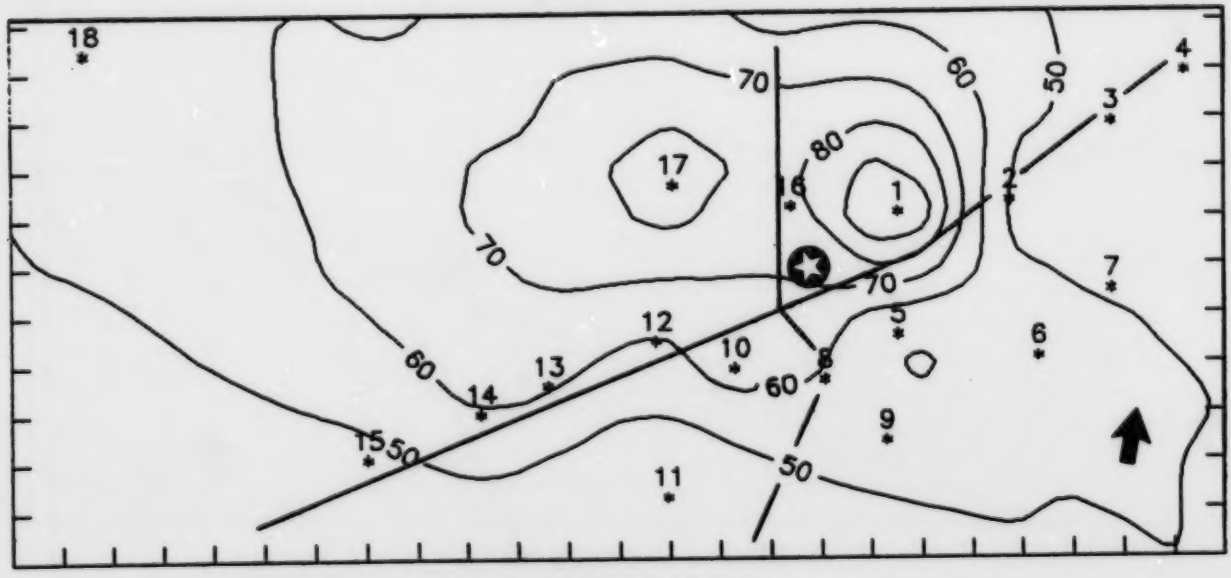
Contour Interval 0.5 ppm

FIGURE: 12 Total Boron Concentrations in 0-5 cm Soil



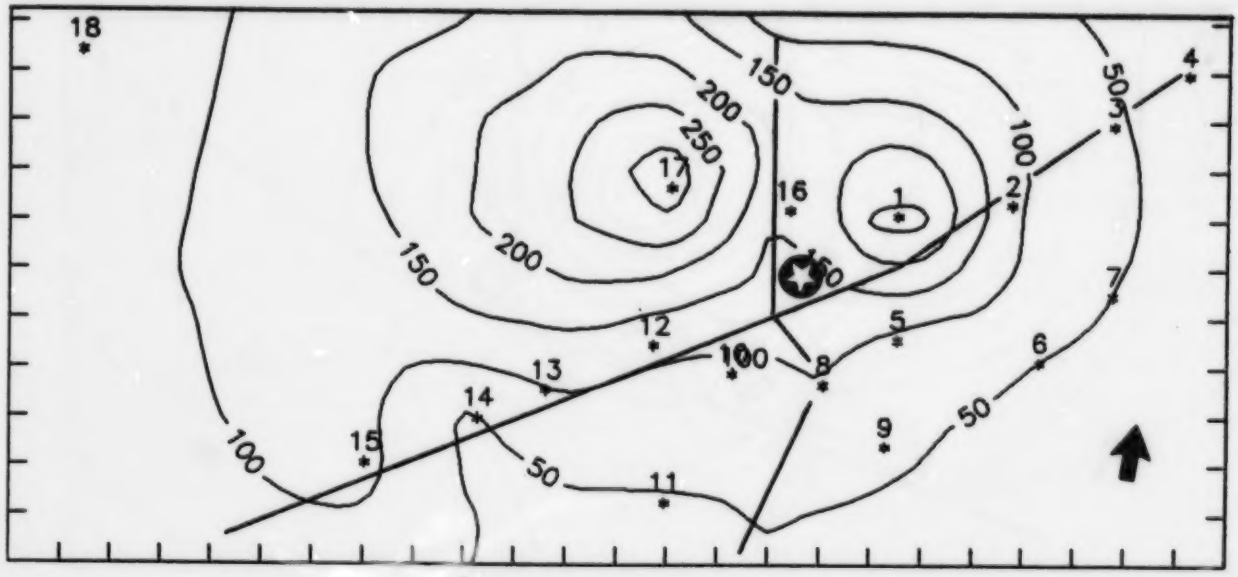
Contour Interval 50 ppm

FIGURE: 13 Fluoride Concentrations in 0-5 cm Soil



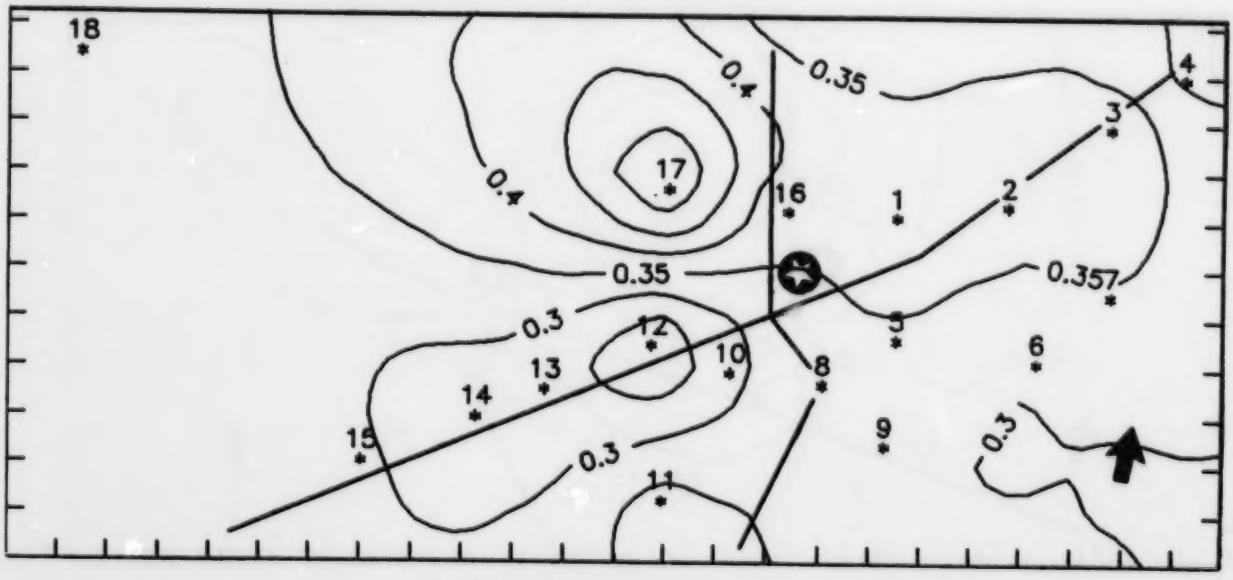
Contour Interval 10 ppm

FIGURE: 14 Barium Concentrations in 0-5 cm Soil



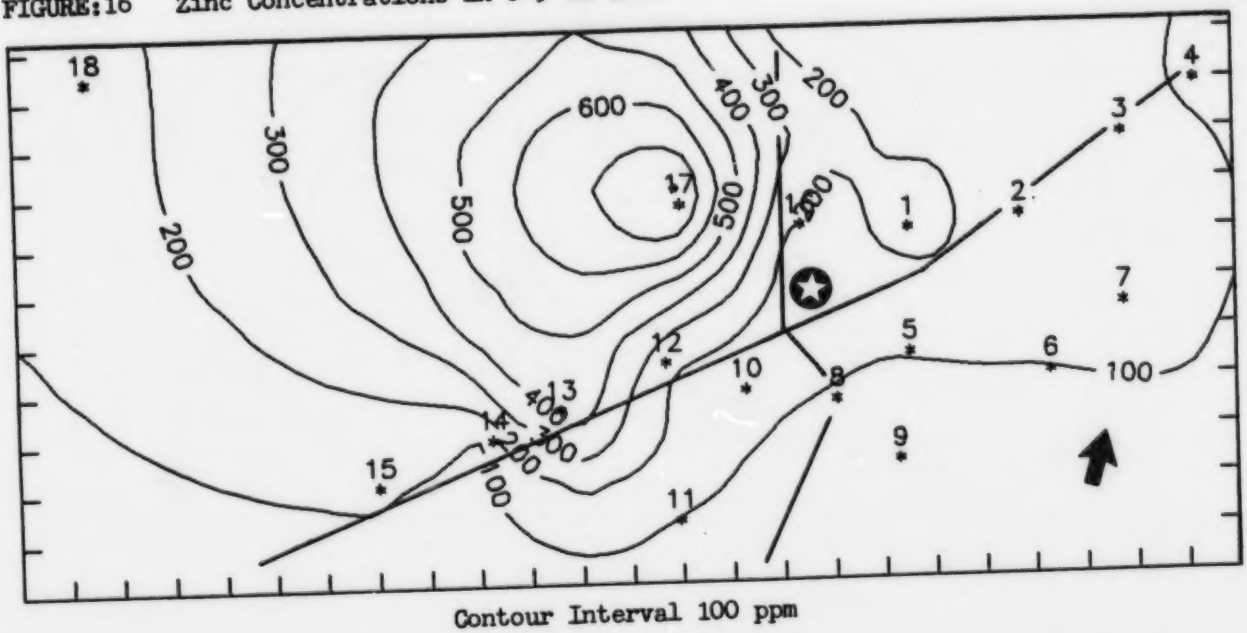
Contour Interval 50 ppm

FIGURE: 15 Titanium Concentrations in 0-5 cm Soil



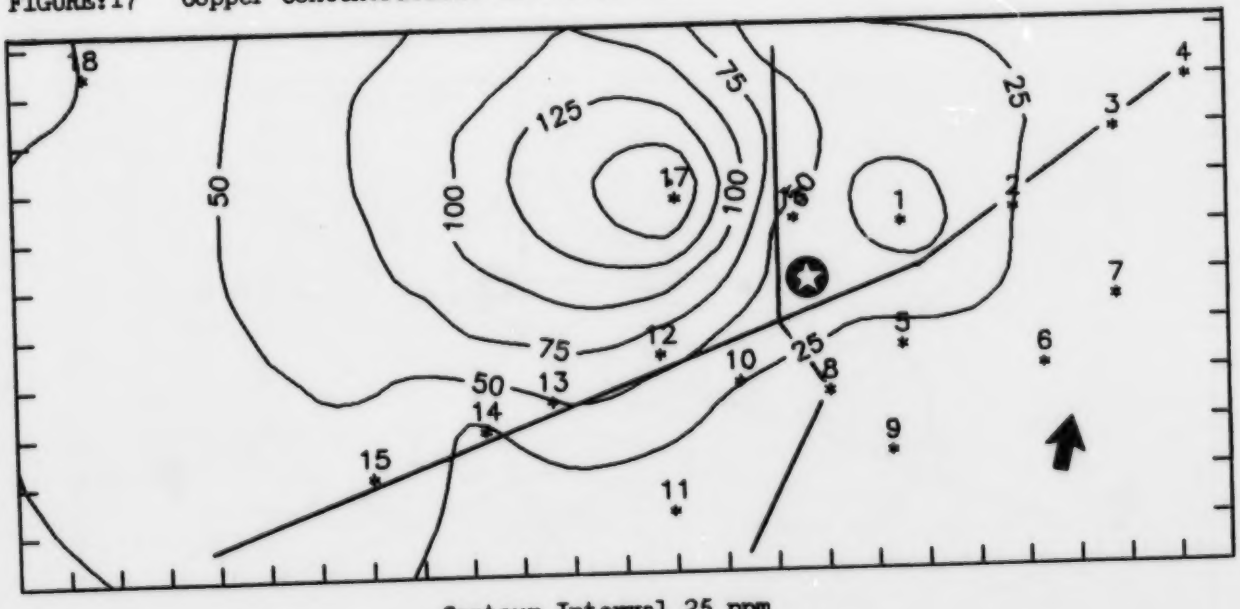
Contour Interval 0.05 ppm

FIGURE:16 Zinc Concentrations in 0-5 cm Soil



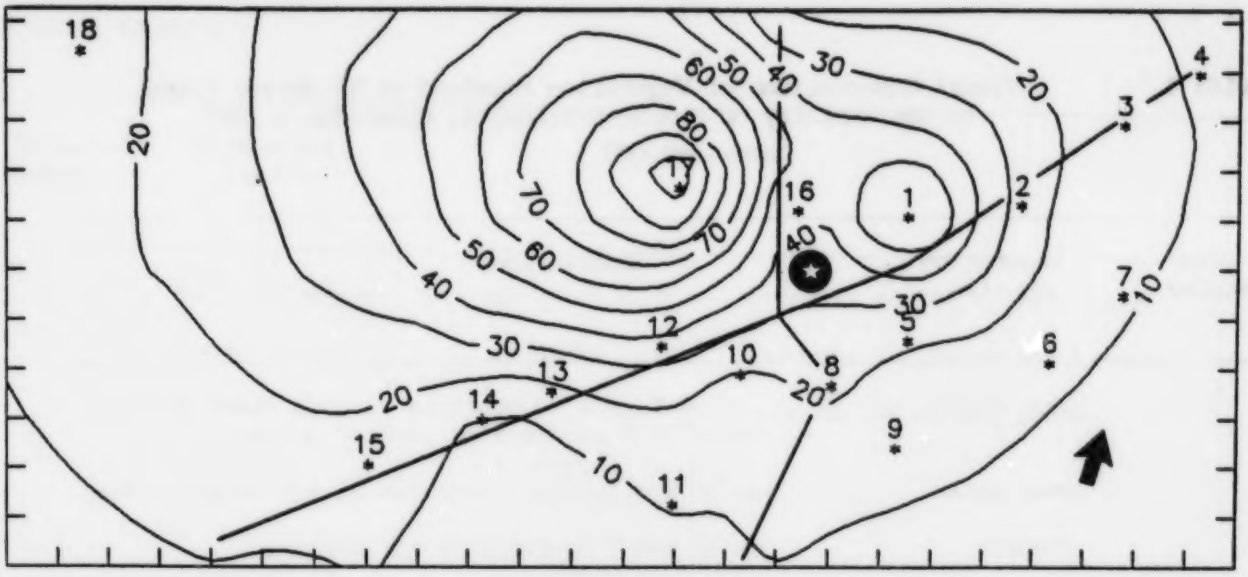
Contour Interval 100 ppm

FIGURE:17 Copper Concentrations in 0-5 cm Soil



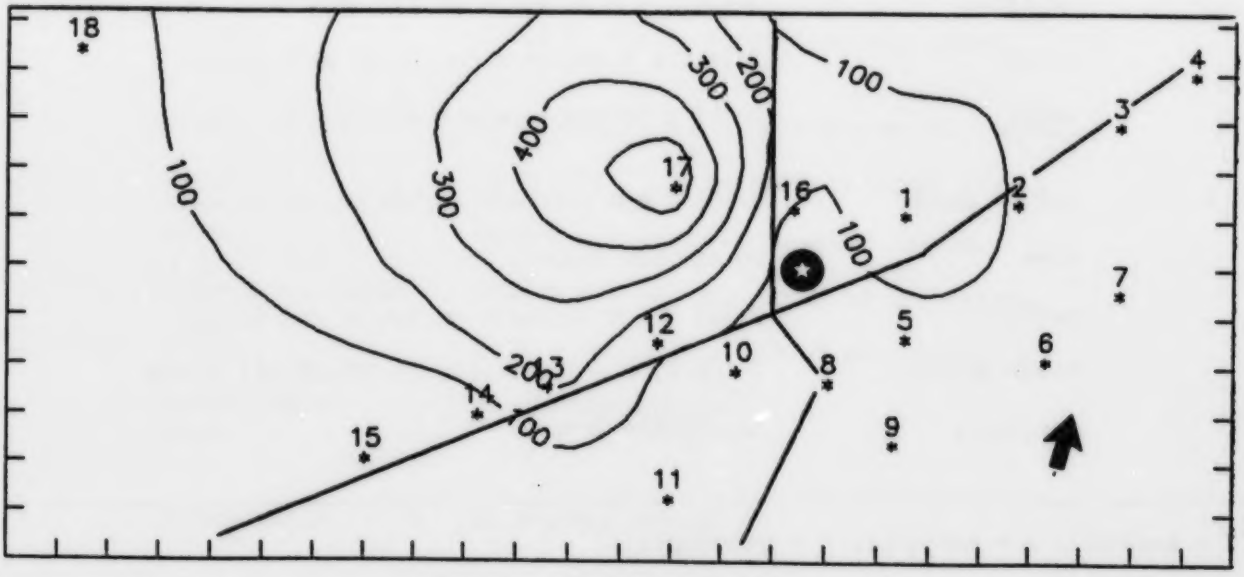
Contour Interval 25 ppm

FIGURE:19 Nickel Concentrations in 0-5 cm Soil



Contour Interval 10 ppm

FIGURE: 18 Lead Concentrations in 0-5 cm Soil



Contour Interval 100 ppm

TABLE: 1 **Visual Observations of Vegetation Examined at 18 Survey Sites in the Vicinity of American-Standard, Cambridge - 1989**

Site Number	Vegetation Species	Observations
1	amur maple	11-35% T, M & I[1] necrosis on most older leaves. 0-1% T & M necrosis on younger leaves.
	amur maple	up to 50% T, M & I necrosis on 99% of all leaves.
	clematis	up to 50% T necrosis on all leaves.
	mountain ash	2-10% T & M necrosis on 99% of all leaves.
	lilac	no visible injury
	horse chestnut	up to 60% T, M & I necrosis on 100% of all leaves.
	rose of Sharon	2-10% injury T, M & I necrosis on older leaves. no visible injury to younger leaves.
	marigold	2-10% T & M necrosis on all leaves.
	tomato	0-1% T & M necrosis on 75% of all leaves.
	larch	2-10% T necrosis on all leaves.
2	silver maple	2-10% T & M necrosis on 70% of all leaves.
	rose	no visible injury.
	marigold	2-10% T & M necrosis on 25% of all leaves.
	black walnut	2-10% T, M & I necrosis on 60% of all leaves.
	raspberry	no visible injury.

[1] T - terminal, M - marginal, I - Intercostal

TABLE: 1 (cont'd)

Site Number	Vegetation Species	Observations
3	Manitoba maple	up to 5% T, M & I necrosis on 20% of all leaves.
	Norway maple	up to 5% T, M & I necrosis on 20% of all leaves.
	spiraea	0-1% T, M & I necrosis on 15% of all leaves.
	raspberry	no visible injury.
	dogwood	" " "
4	silver maple	no visible injury
	Manitoba maple	" " "
	rose	" " "
	raspberry	" " "
	spruce	" " "
	basswood	" " "
	tomato	" " "
5	Norway maple	>35% T, M & I necrosis on all leaves.
	walnut	2-10% T, M & I necrosis on all leaves.
6	bracken fern	up to 60% T, M & I necrosis on all leaves.
	clematis	up to 35% T & M necrosis on older leaves.
	peony	0-2% T & M necrosis on older leaves.
	lily-of-the-valley	0-1% T & M necrosis on 2% of all leaves.
	asters	0-1% T necrosis on 80% of all leaves.
	Norway maple	no visible injury.
	larch	" " "
7	silver maple	no visible injury.

TABLE: 1 (cont'd)

Site Number	Vegetation Species	Observations
8	silver maple	up to 10% T & M necrosis on leaves.
	rose	2-10% T & M necrosis on 80% of all leaves.
	basswood	2-10% T & M necrosis on 100% of all leaves.
	peony	0-1% T & M necrosis on 100% of all leaves.
	currants	2-10% T & M necrosis on 80% of all leaves.
	Norway maple	>35% T, M, & I necrosis on 100% of all leaves.
	tulip tree	2-10% T & M necrosis on leaves.
9	silver maple	0-1% T & M necrosis on leaves.
10	silver maple	0-1% T necrosis on scattered leaves.
	horse chestnut	11-35% T, M & I necrosis on all leaves.
	wild grape	11-35% T, M & I necrosis on leaves.
	walnut	0-1% T, M & I necrosis on all leaves.
	Manitoba maple	up to 20% T, M & I necrosis on 80% of all leaves.
11	Norway maple	up to 2% T & M necrosis on 10% of all leaves.
12	Manitoba maple	up to 50% T, M & I necrosis on 100% of all older leaves.
	wild grape	>35% T, M & I necrosis on older leaves.
	elm	up to 5% T & M necrosis on 90% of all leaves.

TABLE: 1 (cont'd)

Site Number	Vegetation Species	Observations
13	silver maple	up to 15% T & M necrosis on older leaves.
	peony	no visible injury.
	zinnia	" " "
14	Norway maple	up to 35% T, M & I necrosis on leaves.
	elm	0-1% T & M necrosis on leaves.
	Manitoba maple	0-1% T & M necrosis on leaves.
15	silver maple	trace T necrosis on leaves.
16	amur maple	up to 35% T, M & I necrosis on older leaves. incipient I necrosis on younger leaves.
	English oak	up to 80% T, M & I necrosis on all leaves.
17	silver maple	0-1% T & M necrosis on 40% of all leaves.
18 (control)	amur maple	no visible injury.
	silver maple	" " "
	Norway maple	" " "
	white birch	" " "
	Manitoba maple	" " "

TABLE: 2 Concentrations[1] of 8 Elements Detected in Foliage Collected in the Vicinity of American-Standard (A-S), Cambridge - 1989

Sample Site Number	Direction & Approximate Distance from A-S	Vegetation Species Sampled	Element (ppm - oven dry weight) B	F	Ba	Ti	Zn
1	100 m NE	amur maple	895	68	48	31	53
2	225 m NE	silver maple	395	12	9	13	32
3	325 m NE	Norway maple	270	3	10	6	17
4	425 m NE	silver maple	115	4	4	8	33
5	100 m ESE	Norway maple	645	31	17	20	26
6	225 m E	Norway maple	175	6	7	5	12
7	300 m ENE	silver maple	70	3	2	4	32
8	100 m SSE	silver maple	595	67	17	19	56
9	175 m SE	silver maple	240	20	9	9	36
10	100 m SSW	silver maple	255	8	5	6	26
11	235 m SSW	Norway maple	149	5	12	7	23
13	250 m SW	silver maple	190	14	8	11	32
14	325 m SW	Norway maple	270	8	20	8	26
15	425 m SSW	silver maple	120	3	11	8	10
16	60 m NNW	amur maple	1300	33	3	30	56
17	150 m WNW	silver maple	335	14	20	13	83
18[2]	675 m WNW	amur maple	28	5	3	8	16
18[2]	675 m WNW	silver maple	27	4	3	5	24
18[2]	675 m WNW	Norway maple	48	2	8	5	13
Phyto ULN's			**175**	**35**	**NE**	**NE**	**250**

[1]Average of triplicate sample results. [2]Control site.

NE - ULN not established

TABLE: 2 (cont'd)

Sample Site Number	Direction & Approximate Distance from A-S	Vegetation Species Sampled	Element (ppm - oven dry weight) Cu	Ni	Pb
1	100 m NE	amur maple	7.7	5.8	1.9
2	225 m NE	silver maple	5.9	0.7	1.8
3	325 m NE	Norway maple	2.9	0.5	0.9
4	425 m NE	silver maple	4.9	0.5	1.1
5	100 m ESE	Norway maple	6.3	2.7	1.9
6	225 m E	Norway maple	5.2	0.5	0.6
7	300 m ENE	silver maple	10.4	0.5	0.6
8	100 m SSE	silver maple	6.6	1.8	0.8
9	175 m SE	silver maple	4.3	0.5	1.2
10	100 m SSW	silver maple	4.3	0.5	1.1
11	235 m SSW	Norway maple	4.5	0.5	1.7
13	250 m SW	silver maple	3.3	1.0	1.9
14	325 n SW	Norway maple	5.2	0.6	2.0
15	425 m SSW	silver maple	3.0	0.5	1.5
16	60 m NW	amur maple	9.7	8.6	3.4
17	150 m WNW	silver maple	4.8	1.8	2.9
18[2]	675 m WNW	amur maple	4.2	0.5	2.4
18[2]	675 m WNW	silver maple	3.8	0.5	1.2
18[2]	675 m WNW	Norway maple	4.5	0.5	1.1
Phyto ULN's			20	7	60

TABLE: 3 Available Boron Concentrations[1] Detected in 0-5 cm and 25-30 cm Soils Sampled in the Vicinity of American-Standard, Cambridge - 1989

Sample Site Number	Direction & Approximate Distance from American-Standard	Available Boron Concentration[2] 0-5 cm	25-30 cm
1	100 m NE	3.7	1.8
2	225 m NE	1.2	0.8
3	325 m NE	0.4	0.3
4	425 m NE	0.4	0.1
5	100 m ESE	0.8	0.4
6	225 m E	0.4	0.3
7	300 m ENE	0.1	0.1
8	100 m SSE	1.0	1.0
9	175 m SE	0.5	0.4
10	100 m SSW	0.7	0.4
11	235 m SSW	0.1	0.1
12	125 m SW	1.1	0.8
13	250 m SW	0.3	0.3
14	325 m SW	0.2	0.1
15	425 m SSW	0.2	0.2
16	60 m NNW	2.4	0.5
17	150 m WNW	0.5	0.9
18 (Control)	675 m WNW	0.1	0.1
Phytotoxicity Level		1.0	

[1] Average of triplicate sample results

[2] Hot water extract method

TABLE: 4 Concentrations[1] of 8 Elements Detected in 0-5 cm Soil Collected in the Vicinity of American-Standard, Cambridge - 1989

Sample Site Number	Direction & Approximate Distance from A-S	Element (ppm - oven dry weight) B	F	Ba	Ti	Zn
1	100 m NE	130	112	310	0.40	270
2	225 m NE	26	42	105	0.36	115
3	325 m NE	10	47	54	0.39	145
4	425 m NE	5	46	34	0.29	84
5	100 m ESE	13	45	72	0.34	94
6	225 m E	6	59	48	0.30	98
7	300 m ENE	40	49	51	0.35	120
8	100 m SSE	22	60	104	0.34	95
9	175 m SE	14	55	60	0.30	78
10	100 m SSW	15	66	85	0.29	140
11	235 m SSW	2	33	46	0.38	95
12	125 m SW	56	57	109	0.18	180
13	250 m SW	17	62	105	0.28	535
14	325 m SW	5	60	33	0.25	84
15	425 m SSW	7	47	115	0.31	115
16	60 m NNW	29	72	125	0.35	110
17	150 m WNW	240	89	355	0.57	865
18[2]	675 m WNW	3	53	59	0.32	150
Phyto ULN's		15	NE	NE	NE	500

[1]Average of triplicate sample results. [2]Control site.

NE - ULN not established.

TABLE: 4 (cont'd)

Sample Site Number	Direction & Approximate Distance from A-S	Element (ppm - oven dry weight) Cu	Ni	Pb
1	100 m NE	72	70	235
2	225 m NE	21	23	76
3	325 m NE	17	14	44
4	425 m NE	12	9	30
5	100 m ESE	16	17	41
6	225 m E	16	12	44
7	300 m ENE	14	11	31
8	100 m SSE	22	24	27
9	175 m SE	17	14	24
10	100 m SSW	22	17	63
11	235 m SSW	11	11	22
12	125 m SW	58	36	91
13	250 m SW	53	15	240
14	325 n SW	15	8	27
15	425 m SSW	47	18	10
16	60 m NW	27	32	24
17	150 m WNW	190	115	620
18[2]	675 m WNW	23	14	58
Phyto ULN's		**100**	**60**	**500**